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Application of Particle Swarm Optimization in Hydro and Photovoltaic Design: A Review

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Abstract:

Hydro and photovoltaic are two main renewable energy sources that are currently being used in Malaysia. This paper aims to look into the potential of using Particle Swarm Optimization (PSO) in Hydro and Photovoltaic Design. Recent research shows that PSO can be used for optimal sizing of stand-alone photovoltaic system and optimization of mini hydro power plant design. Proper selection of mini hydro-power plant components such as turbine type, penstock size, and net head length needed to be done as they are the major components of the power station. While PV modules, charge controllers, inverters and batteries are the components involved in a Stand -alone Photovoltaic (SAPV) system. For Photovoltaic system, the sizing processes considered the quality of solar irradiation received by the geographical location, the effect of temperature d-rating, the efficiency of components, the selection of system voltage, the number of days of autonomy, and the demand for electricity. However, the parameters of mass flow rate, practical head and efficiency of generator and turbine will be considered for the desired outputs of the design of hydropower generation. PSO are mostly the same as those obtained from the computational method. Based on the review that has been made, the PSO algorithm has already been used by recent researchers for optimising purposes. The benefit of PSO includes simple concept, easy implementation, reliability to control parameters, and computational efficiency.

Keywords **—PSO, Hydro, Photovoltaic, Review, Renewable Energy.**

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I. INTRODUCTION

In industrial revolution era, the conventional energy nowadays was proven to be highly leading in economic growth. However, conventional energy such as oil, coal and natural gas are actually contributing to global warming and consequent climate change. Renewable energy such as solar, wind, hydropower, biomass, geothermal are another alternative resource of clean, everlasting and increasingly competitive energy that should be highlighted to provide sustainable energy service. Most of the country around the world are now reconsider about the changing of conventional energy to renewable energy.

One of the most common types of renewable energy is hydropower. Due to the size of hydropower that quite gigantic and need higher cost, thus mini hydropower plant was introduced. Mini-Hydropower require no dam or other costly civil construction since they are run-of-river hydro systems. Mini hydro is a hydropower station that produces 100 standard units of electricity in one hour and has a power rating of 1MW or less. Mini hydropower is a small-scale energy generation method that converts kinetic energy into electric energy from falling water, such as steep mountain rivers. The mini hydropower system's concept is to use a turbine to generate mechanical power from

water pressure, which is subsequently converted to electrical power. Mini-Hydropower require no dam or other costly civil construction since they are run-of-river hydro systems.

A photovoltaic (PV) cell is a device that converts sunlight into electrical energy. Each of these cells is quite small, and they are connected to form larger units known as modules, which can be connected to form an even larger unit known as PV array. For meeting the required electricity demand, these arrays are connected in parallel and series formations. Since PV arrays generate electricity only when they are illuminated, it is necessary to employ a large energy storage system, which is most commonly a series of rechargeable batteries. A charge controller and converters must also be installed to prevent harmful battery over-charge and over-discharge conditions, as well as to drive alternating current loads. Solar photovoltaic (PV) systems can be used to harvest solar energy in almost any application. Photovoltaic (PV) systems can be categorized into three types based on the approach of utilization, namely, SAPV system, grid-connected PV system, and hybrid PV system, respectively.

Particle Swarm Optimization (PSO) is a biologically inspired computational search and optimization approach created by Eberhart and Kennedy in 1995 that is based on the social behavior of flocking birds or schooling fish. When compared to mathematical algorithms and other heuristic optimization approaches, the main advantages of the PSO algorithm are simple concept, straightforward implementation, resilience to control parameters, and computing efficiency. PSO is best used to find the maximum or minimum of a function defined on a multi-dimensional vector space. In this project, the PSO algorithm will be used to optimize renewable energy which is design mini-hydropower plant and sizing photovoltaic system.

II. PSO FOR HYDRO DESIGN

The researchers in [1] have stated that among the many functions of the reservoir, determining appropriate operation rules for reservoir discharge in order to maximise hydropower output is critical. The focus of this research was to optimise reservoir release to increase hydropower generation at Aliyar reservoir in Tamilnadu's Coimbatore District. They have found that using PSO-optimized release patterns leads to a significant increase in hydropower generation. In the future, this research will focus on applying bio-inspired algorithms to forecast reservoir inflow and predict the related optimal release, which could boost power generation even further.

Next, the researchers in [2] found out that this study was required prior to the development of the Mini Hydroelectric Power Plant on PulauTemerloh, Pahang. Using a hydrological analysis method and a hydrological model, the hydroelectric potential of Sg Pahang at Temerloh was evaluated. It is crucial to examine the present river flow characteristics and simulate the environmental river flow evaluation. The findings indicate that the water resources are considerable, hence enhancing the mini hydropower potential of Sg Pahang.

Then, the researchers in [3] stated that a mathematical model was created, and particle swarm and genetic algorithm optimization techniques were used to optimise energy generation. The use of optimization techniques to the proposed mathematical model increased power output, according to the findings. For the Mangla hydropower station, a mathematical model was created, and particle swarm and genetic algorithm optimization techniques were used to optimise energy generation. The results showed that the Genetic Algorithm can generate the most electricity when compared to particle swarm optimization, but particle swarm optimization takes significantly less time to execute than the Genetic algorithm.

Besides that, the researchers in [4] found that Optimization studies are critical for determining the

economic feasibility of any project before it is implemented. The particle swarm optimization approach, often known as PSO, was employed in this work to optimize the benefit cost ratio derived from the hydro power plant. The PSO approach is the most recent of the several optimization techniques accessible today, and it has never been employed for hydro power plant optimization. A case study was provided in a publication, and the benefit-cost ratio achieved was far above unity, indicating that the power plant is feasible. In the construction of hydro power plants, in addition to the solo benefit cost ratio, there are a significant number of indirect advantages such as social benefit, environmental benefit, and so on.

The researchers in [5] have concluded that in the past, numerous powers producing units were created in response to the rising need for electricity. The objective of hydro scheduling is to maximize the gross utilization of the power produced of big cascaded hydropower facilities across all specified time intervals. The paper describes several optimization strategies for the hydro scheduling issue. It compares the approaches qualitatively and quantitatively. It may be of great value to academic authors in the subject of problem resolution. The paper compares qualitatively and statistically the many optimization approaches to the hydro scheduling problem that are described

The researchers in [6] implemented the golden era of hydropower occurred in the early part of the 20th century before oil control dominated the energy industry. It is due to the benefits of Firefly Algorithm's meta-heuristic approach, which thoroughly cleans the searching region to find the ideal answer. This project's purpose is to include both Firefly Algorithm (FA) and Particle Swarm Optimization (PSO) into the hydroelectric plant located at the Lake Himreen dam. FA is a stochastic method that relies on the attraction and light intensity of firefly behavior. Due to the algorithm's growing values throughout the course of each iteration, the PSO convergence approach is incapable of achieving any period for stable cases.

Furthermore, the researchers in [7] stated that for hydroelectric power plants transform potential energy or water into electricity, this is a clean energy source. After producing electricity, water may be used for irrigation and other uses. The primary purpose of this article is to examine the development potential of micro hydropower. The design procedure consists mostly of a micro hydropower plant's global estimate. They conclude MATLAB software can be used to compute the fundamentals of a micro hydro power plant, such as the power, head, and flow, but it is difficult to design a programmed that can determine the type of turbines that can be utilized based on the supplied parameters.

The researchers in [8] found that a proposed PSO-based solution for tackling the daily hydrothermal coordination scheduling issue for hydro units. One of the benefits of the suggested method is the adaptability of PSO for modelling different constraints. This research provides a proposed PSO-based solution for tackling the daily hydrothermal coordination scheduling issue for hydro units. One of the benefits of the suggested method is the adaptability of PSO for modelling different constraints.

Apart from that, researchers in [9] implemented this paper proposes a new PSO-based method for solving short-term hydrothermal scheduling issues using the reservoir volume as the particle location. This work also discusses software designed for short-term hydro-thermal scheduling, considering hydro economic dispatch and thermal unit commitment. Using the reservoir volume as a particle, they suggest an alternate method for solving short-term hydro-thermal scheduling issues in this research. Using the reservoir volume as a particle, they suggest an alternate method for solving short-term hydro-thermal scheduling issues in this research.

The researchers in [10] found out that article described the use of the Evolutionary Particle Swarm Optimization (EPSO) algorithm to the optimization of a collection of hydro stations. the requirement for generating firms to maximize the use of their generation assets in light of market pricing, this topic has acquired increased attention. With this work and the MSc Thesis on which it is based, they aim to have made a further contribution to the creation of potent tools that assist generating businesses in optimizing the operation of their portfolios.

III. PSO FOR PV DESIGN

The researchers in [11] have stated that the share of PV power used, as well as the use of a diesel generator and/or a battery, is determined by the operating modes chosen. They have found out that the developed PSO algorithm provides other significant parameters in addition to the obtained optimal configurations for sizing optimization. In four cities in Morocco, Spain, and Algeria, the particle swarm optimization (PSO) method is used to optimise a hybrid system for 20 years of operation. They have concluded that the PV power is generated in a time interval ranging between 9 and 17 h.

Next, the researchers in [12] found out that the increasing demand for energy, the depletion of fossil fuel resources, and global warming always encourage energy system designers to improve their designs. The researchers have implemented a multi-objective particle swarm optimization (MOPSO) method for optimal sizing of the standalone photovoltaic (SAPV) systems. They have concluded that the optimum design was chosen by minimizing objective function based on loss of load probability (LLP), life cycle cost (LCC), and levelized cost of energy (LCE) criteria.

Then, the researchers in [13] stated that Stand-Alone Photovoltaic (SAPV) systems have become a popular mode of electricity generation, mainly in places where grid electricity is unavailable. However, one of the most challenging aspects of developing these systems is determining the best system size. They found out the number of PV modules in series, the number of parallel PV strings, the number of batteries per string, the number of parallel strings of batteries, and the inverter power capacities are all determined during the sizing process. The study revealed that a CSO-based algorithm was successfully used for SAPV system sizing optimization in Kalabakan, Tawau, Sabah, Malaysia.

Besides that, the researchers in [14] found out that the traditional farmland irrigation mode is transformed into mobile sprinkler irrigation with high uniformity of irrigation by a solar-powered translational sprinkler irrigation machine. They propose that the optimal sizing of a stand-alone photovoltaic system for a solar-powered translational sprinkler irrigation machine considering the loss of power supply probability is an important issue.

The researchers in [15] conclude that he V-I characteristics of a photovoltaic generator are nonlinear in nature and vary with irradiation and temperature. For varying insolation values, the control unit optimises the duty cycle in real time to control the boost converter and make the PVP operate at maximum power. At various irradiance and temperature levels, they are achieving 99 percent or higher effectiveness in tracking maximum power point.

The researchers in [16] presents the technical validation results for two different control algorithms implemented for the compressor of the HP unit which are the Maximum Power Point Tracking control (MPPT) and the inverter control, for a stand-alone PV-HP system operating without batteries. They found that in the interior and exterior rooms, the two auxiliary heat pumps assisted in simulating warm conditions. At a

temperature of 30 °C, both heat pumps were set to heating mode. The interior auxiliary heat pump compensated for the PV-HP unit's cooling energy, while the exterior auxiliary heat pump simulated summer conditions.

Furthermore, the researchers in [17] stated that Friction stir welding (FSW) is a newly developed solid-state process that uses frictional heat to join dissimilar materials. FSW eliminates all flaws found in the fusion welding process, including oxidation, porosity, voids, and the formation of harmful phases. Based on their finding, the current study used a MATLAB-coded PSO algorithm to test the applicability and effectiveness of the proposed algorithm on FSW process parameters. They found out that in terms of solution precision and convergence speed, the particle swarm optimization (PSO) algorithm performed admirably.

The researchers in [18] found out that as the world moves toward an AI-centric professional market, it is critical to keep up with the trend and provide solutions for optimising and increasing the efficiency of solar industry design and development. They have concluded that PVsyst and AutoCAD are the most widely used and efficient methods due to their ability to perform various evaluations.

Apart from that, researchers in [19] implemented a prediction method to predict the electricity consumption in order to address the problems of big change and imbalance in electricity consumption caused by COVID-19. They found out that the BP (Back Propagation) neural network and improved particle swarm optimization (IPSO) algorithm model performs well in terms of prediction.

In addition, the researchers in [20] found out that temporal convolutional networks and long short-term memory networks are used to create a new prediction method for reservoir evaluation parameters. The sweet spot is discovered, allowing the well to be positioned quickly and accurately, increasing the drilling rate and oil-gas production. They found out that the combination model was optimised using particle swarm optimization, which allows the optimal parameters to be found quickly.

IV. CONCLUSION

Based on the review that has been made, the PSO algorithm has already been used by recent researchers for optimising purposes. The benefit of PSO includes simple concept, easy implementation, reliability to control parameters, and computational efficiency. Not to mention, the application of PSO to meet each of every researcher's objective are increasing as more research being done by implementing PSO. It is also widely used for its convenience, not only by experts but also by beginners to renewable technology. For future research, exporting the hydro and PV designer tool MATLAB application as a stand-alone application could be done so non-MATLAB users will be allowed to install and use the application without restriction.

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